V2X Communications: The Killer Application of Millimeter Wave

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Motivation
The era of connected vehicles

Key element for the new generation Intelligent Transportation Systems

Governments are pushing for the connected car revolution

- NHTSA has announced intention to require DSRC in new cars by 2017

What is the difference?

CONNECTED

V2X communication capabilities

AUTOMATED

Some safety-critical control functions
without direct driver input

AUTONOMOUS

Self driving capabilities
without connectivity

M. Parent, "Automated Vehicles: Autonomous or Connected", IEEE 14th International Conference in Mobile Data Management (MDM), vol.1, no., pp.2-2, 3-6 June 2013
Trends in the automotive sector

- To achieve higher automation levels, connectivity seems critical
- Vehicular communications to share sensing data and enhance sensing capability

New challenges for the underlying communication system

*5G-PPP White Paper on Automotive Vertical Sector, October 2015, https://5g-ppp.eu/white-papers/
## Summarizing automotive sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Purpose</th>
<th>Drawback</th>
<th>Data rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar</td>
<td>Target detection, velocity estimation</td>
<td>Hard to distinguish targets</td>
<td>Less than 1 Mbps</td>
</tr>
<tr>
<td>Camera</td>
<td>Virtual mirrors for drivers</td>
<td>Need computer vision techniques</td>
<td>100-700 Mbps for raw images, 10-90 Mbps for compressed images</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Target detection and recognition, velocity estimation</td>
<td>High cost</td>
<td>10-100 Mbps</td>
</tr>
</tbody>
</table>

Is it possible to exchange raw sensor data between vehicles?

Automotive sensors generate a huge amount of data.
Massive data rates from sensors vs DSRC/4G

- Connected vehicle is expected to drive 1.5GB monthly mobile data in 2017
  - May be handled with a combination of conventional cellular and DSRC
- Autonomous vehicles can generate up 1 TB per hour of driving
  - 4G and DSRC can not support these data rates

New communication solution is needed for connected cars

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Millimeter wave for connected cars

MmWave is the only viable approach for high bandwidth connected vehicles.
Challenges and research lines
How will mmWave be realized?

5G is promising for mmWave connected cars

- **5G mmWave cellular**: Uses cellular infrastructure, Access is highly coordinated, Leverages (coming) mmWave spectrum
- **Modification of IEEE 802.11ad**: Less efficient access, Use of unlicensed band
- **High data rates**: Requires special infrastructure
- **Dedicated mmWave V2X**: Use new dedicated spectrum

Challenges for mmWave in V2X

Lack of propagation channel models

Typical antenna height: 1.5 m

High penetration rate needed for most gains

More infrastructure

Communication overhead

Implications of using mmWave in automotive

- Increased sensing capability in the car
- Joint automotive radar and communication is possible
- New kinds of infrastructure to be deployed near roads
- Sensing technologies can be used to help establishing communications
Using position information to reduce beam alignment overhead in mmWave V2X

- Each vehicle decides candidate beams from other vehicles’ position and size info

DSRC modules or automotive sensors can be used to reduce overhead

Adding radar to the infrastructure

- A BS with a radar can capture information of the scattering environment
- Used to design multiuser beamforming, support remote car traffic control

Sensing at the infrastructure can help in establishing the communication links

Predicting blockage from out-of band sensing

- Radar can detect potential obstacles and their associated mobility
- Machine learning can classify particular radar responses as blockages

Sensing & learning are symbiotic technologies

Joint radar and communications based on 802.11ad

- IEEE 802.11ad mmWave waveform works well for radar
  - Special structure of preamble enables good ranging performance
  - Leverages existing WLAN receiver algorithms for radar parameter estimation

- Target vehicle information from 11ad radar can be directly used for communication

Joint system provides safety capabilities at lower cost

Conclusions

Why mmWave V2X?
• Provides the only high data rate solution for sensor exchange
• Already used in other automotive technologies

Why 5G?
• Already exploring a mmWave waveform
• Will operate in dedicated spectrum with heavy management
• Will support lower frequencies as a backup

MmWave V2X MmWave introduce new challenges
• Lack of propagation channel models
• New signal processing techniques need to be developed
• Infrastructure and penetration rate